Report on the NOAA Hydrometeorology Testbed–Southeast (HMT-SE) Research Planning Workshop

June 15-17, 2009
Chapel Hill, North Carolina

Executive Summary

The NOAA Hydrometeorology Testbed-Southeast (HMT-SE) Research Planning Workshop, hosted by the State of North Carolina-sponsored Renaissance Computing Institute (RENCI), was held in Chapel Hill, NC on 15-17 June, 2009 and facilitated by staff of the NOAA National Ocean Service (NOS) Coastal Services Center (CSC) as a Southeast and Caribbean Regional Team activity. It was the second of two planning workshops for HMT-SE and was designed to complement and build upon the first – the *HMT-Southeast Operational Needs and Requirements Workshop*, which was held on 3-5 February 2009. The primary outcome of Workshop #1 was the definition of over forty requirements related to hydrometeorological information and technologies, formulated to address identified operational gaps and needs in the Southeast region. The principal focus of this, second workshop was to identify the research and development needed to address those requirements and facilitate the transition of newly identified science and technologies into operations. The over-arching purpose of the two workshops is gather information to inform the development of a science plan that will guide the experimental design of the upcoming, field phase of HMT-SE.

Approximately 70 individuals attended the workshop, from diverse backgrounds in the research, forecast and operations, and emergency management communities (a list of attendees is available from ftp://ftp.etl.noaa.gov/user/hmt/HMT-Southeast/Workshop-2/). The morning sessions of the first day included welcomes and introductions, and several presentations, which were provided to bring the general audience to a common level of understanding on the background and context of HMT-SE. Presentations were given on the desired outcomes and objectives of this workshop, the geological and climatological characteristics of the region, and some particular meteorological and hydrologic challenges in and around the Tar-Neuse Basin. The afternoon of the first day and morning of the second were dedicated to breakout sessions organized along the four theme areas identified in Workshop #1, i.e. (1) Quantitative Precipitation Estimation (QPE); (2) Quantitative Precipitation Forecasting (QPF); (3) Hydrologic/ Hydrodynamic Applications & Models (HA); and (4) Decision Support Systems (DSS) and Societal Impacts (SI). The key objectives of these breakout sessions were the prioritization of the requirements in each theme area and identification of the research, development and field demonstration challenges and opportunities associated with those requirements.

In the QPE theme area, the upcoming testbed was seen as an opportunity to utilize new technologies that can distinguish hydrometeor types, sizes and distributions, such as disdrometers, vertically pointing radars and dual polarization radars (the fact that the Morehead City, NC WSR-88D radar will be a dual polarization beta site was cited as an important opportunity to be exploited). The utilization of dense, ground-based observation (e.g. rain gauges) to investigate rainfall distribution and perform error assessment was also cited. In the QPF area, it was recommended that, temporally, the focus should be on shorter-term forecasts, as opposed to climate-scale or even 5-day, but that spatially, the convective through synoptic scales would have to be considered. It was recognized that the burgeoning area of probabilistic QPF would be important to address in the testbed, but that the communication of probabilistic information to the general

public would bring significant challenges, necessitating the development of new tools for forecasters. In the Hydrologic/ Hydrodynamic Modeling theme area, there was considerable focus on the areas of analysis of river forecasting performance, review of current monitoring capabilities, and determination of appropriate benchmarks for assessment. Also cited was the need to support modeling efforts through the acquisition of diverse observations, in order to capture phenomena such as flow (measured both horizontally and vertically) and the highly non-linear interactions between terrestrial runoff, bank overflow and storm surge, across a wide range of spatial and temporal scales. And in the DSS and SI area, the need to develop models and provide products at increased spatial and temporal resolution was noted as a priority area, as well as the capability to more effectively access and disseminate existing data sets (such as inundation maps).

Across these themes, there was recognition that a vital element of HMT is the transition of research to operations (R2O). The capabilities of individual RFCs and WFOs, regarding processing power, storage, and bandwidth, may need to be enhanced to support potential new applications. IT/computing support to allow the execution of models as well as the transfer, display, and archiving of data will also be very important. Furthermore, the issue of training for WFO and RFC forecasters will be essential for successful R2O. The likelihood that various research techniques may eventually be brought successfully into operations will be an important criterion when considering which of them will be incorporated into the field phase of HMT-SE.

The afternoon of the second day began with a plenary session in which representatives provided report-outs from each breakout group. This was followed by a panel discussion with a moderator, five panelists and audience participation, on facilitating the transition of newly identified capabilities into operations. The third and final day included additional, morning plenary sessions in which the results of the earlier sessions were clarified and summarized, the challenges of the resource acquisition process (through the NOAA Planning, Programming, Budgeting and Execution System (PPBES)) were discussed, and general observations and perspectives of the workshop participants were solicited and recorded.

The complete agenda and related files can be found at the HMT-SE FTP site:
ftp://ftp.etl.noaa.gov/user/hmt/HMT-Southeast/Workshop-2/

Some of the key results of the workshop came out of the breakout sessions, during which a research template (provided) was filled out, in sections, for each of the four theme areas. Topics addressed included the type of activity, nature of effort, geographic scope, type of basin, estimated effort, research-to-operations issues, and 'ownership' (i.e. who would take the lead) associated with each requirement. Another key session was the panel discussion on Research-to-Operations (R20), which brought focus to the many issues and steps along the way of successfully transitioning identified capabilities into operations.

Workshop Background and Objectives

The NOAA HMT-SE Research Planning Workshop was held over a two-and-a-half day period in Chapel Hill, NC on June 15-17, 2009. It was the second of two scheduled planning workshops, with a focus on hydrometeorological modeling, research, and transitioning of research into operations. The primary objectives of this workshop were to:

- Review the history of the Hydrometeorology Testbed and the outcomes from the first HMT-SE workshop, so as to provide context for common dialog among all participants.

- Identify and prioritize key research, development, and field demonstration "challenges" and "opportunities" needed to respond to requirements that were identified during Workshop #1, grouped in four primary theme areas.
- Summarize results within each theme area and look for commonalities and potential efficiencies across the themes.
- Determine how to facilitate the transition into operations of new or upcoming capabilities that have been evaluated through the testbed as having relevance and viability.
- Identify the resources available and needed to meet the various HMT-SE objectives, and strategies for obtaining those resources.

Outcomes

The principal outcome of this workshop was to generate and consolidate information on the hydrometeorological research activities in the region that will inform the development of the HMT-SE Science Plan, describing the research, development, and field experiments to be conducted during the field-operations phase of HMT-SE (presently anticipated to begin in 2011 and extend through 2015). The *HMT-SE Operational Needs and Requirements Workshop* in February (Workshop #1) provided a framework upon which to organize this information, through a process of iterative refinement of the operational requirements that were documented in Workshop #1 in four primary "theme areas": (1) Quantitative Precipitation Estimation (QPE); (2) Quantitative Precipitation Forecasting (QPF); (3) Hydrologic/ Hydrodynamic Applications & Models (HA); and (4) Decision Support Systems (DSS) and Societal Impacts (SI).

Participants

Approximately 70 individuals attended the workshop from diverse backgrounds in Federal, state, and local organizations (including county forecast, warning and emergency management agencies), as well as academic institutes. Federal attendees were primarily from NOAA but also included representatives from the National Aeronautics and Space Administration (NASA) and the U.S. Geologic Survey (USGS). State and local agencies from North Carolina included the State Climate Office and Geospatial and Technology Management Office, the host organization (RENCI), and the Wake County Soil and Water District (which includes the city of Raleigh). About a dozen academic and research institutes were represented, including numerous state and private universities in the Carolinas, and the National Center for Atmospheric Research (NCAR) in Boulder, CO. A list of attendees can be found at the ftp site provided above.

Figure 1 is a group photograph including the majority of the participants at the workshop.

Workshop Major Themes and Sessions

Setting the stage for the Workshop

The first morning of HMT-SE Workshop #2 was devoted to familiarizing the diverse audience members (some of whom had attended the first workshop and some of whom had not) with the general history and purpose of the Hydrometeorology Testbed, events to date on the planning effort in the Southeast U.S. (including the outcomes of HMT-SE Workshop #1), and the physical context of the geography, climatology, and common hydrometeorological challenges of the Tar-Neuse Basin and vicinity. Presentations were provided on topics including:

- A background description of HMT, HMT-SE, and expected use of the results of the two workshops (presented by Allen White);
- HMT-SE Workshop #1 and its documented requirements, by theme area (presented by Darin Figurskey);
- Regional hydrometeorology and climatological context (presented by Phil Badgett).

Links to these presentations can be found at the HMT-SE FTP site (see above):

Refining the requirements from Workshop #1

During the afternoon of the first day and morning of the second, breakout sessions were held, organized along the four theme areas identified in Workshop #1 (see above), with key objectives being the identification of the research, development and field demonstration challenges and opportunities associated with each requirement, and the prioritization of those requirements. Discussions in each group progressed toward completing the various sections of the provided templates that will help to create the framework for the HMT-SE Science Plan, which is the principal, desired outcome of these workshops.

The afternoon of the second day began with a plenary session in which representatives provided report-outs from each breakout group. In each report-out, an overview was given of the number and nature of the requirements in that theme area, their priorities as assigned by the group, and highlights of key discussion points that occurred during deliberations.

Panel discussion on Research to Operations

Following the report-outs on the requirements, a panel discussion was held on how to best transition research to operations (R2O). It was moderated by Jeff Waldstreicher (NWS/Eastern Region Headquarters) and included panelists John Feldt (NWS/Southeast River Forecast Center), Gary Lackmann (NC State University), John Billet (NWS/Weather Forecast Office, Wakefield, VA), Geoff Bonnin (NWS/Office of Hydrologic Development) and Woody Roberts (OAR/Earth System Research Laboratory). Some of the discussion themes were how R2O presently occurs in field offices, what their experiences with transitions have been in the past, and what the perceptions of the scientific and operational communities are of each other. One important perception that emerged from the operational side was that the field offices tend to have limited opportunities, among higher priority operational responsibilities, to effectively implement and assess new applications. More on R2O is found, below, in the 'Results' section.

Open discussion

On the morning of the final day, another plenary session was held in an open format to provide an opportunity for review, clarification, and discussion of topics that may have been overlooked. Some of the discussion highlights were:

- Sensor projects that are being planned or trying to acquire funding, including ones by the U.S. Forest Service and Wake County, NC
- Consideration of possible redefinition of the geographical domain of HMT-SE
- Strategizing on approaches to acquire funding
- "Selling" the testbed program by emphasizing the applicability of experiments conducted locally to broader geographic regions
- Utilizing the tenth anniversary of the landfall of Hurricane Floyd in NC as an opportunity to advocate for the HMT program

Results

The stated, desired outcomes of the workshop were:

- To help identify the research and development needed to address the operational gaps and requirements (identified during Workshop #1)
- To identify new science and technologies that can be demonstrated, evaluated, and transitioned to forecast operations
- To inform the experimental design of HMT-SE and the development of a Science Plan

Research and Development needed to address requirements:

The first stated workshop outcome was addressed during the breakout sessions and plenary sessions that ran from the early afternoon of the first day through mid afternoon of the second day. As discussions occurred during these sessions, the four provided research templates were filled in on a requirement-by-requirement basis and reported on. Full details on the proposed R&D solutions are contained in the completed templates, which can be found at:

ftp://ftp.etl.noaa.gov/user/hmt/HMT-Southeast/Workshop-2/

Some of the key discussion topics during the breakout sessions, and highlights of the templates, follow:

Quantitative Precipitation Estimation (QPE)

The Quantitative Precipitation Estimation (QPE) breakout group retained the six requirements identified during Workshop #1 with few changes, but revised the order of priority. The requirement titled "Assess the adequacy of QPE to evaluate catchment scale water budgets and stream flow response" was elevated from the lowest to the highest priority on the reasoning that it serves as an overarching umbrella encompassing the other requirements. The remaining (five) requirements were retained in essentially the same priority-order as originally determined: two of these are focused on hydrometeor validation devices including rain gauges and disdrometers; two more are concerned with weather radar; and the last addresses satellite-based QPE.

In filling out the R&D Activities Template, the central focus of the group was on the requirements-to-operations process. For each requirement, numerous (three to eleven),"R2O Issues, Opportunities & Challenges" were first identified in a brainstorming session. Then the other

themes of the template, such as Description of Activity, Nature of Effort, Geographic Scope, etc., were addressed on an issue-by-issue basis. Some key discussion points per requirement were as follows:

- **Assess adequacy of QPE to evaluate … water budgets and stream flow response:** Data from the Multisensor Precip Estimator (MPE) application at the RFCs can be used to establish a baseline for comparison of various QPE methodologies. Verification possibilities include 24-hour cooperative observer ("COOP") reports as well as ASOS, RAWS, AWOS and CoCoRaHS. The Q2 multi-sensor application should also be evaluated. Historical data can be used to perform initial analysis before commencement of actual field experiments. The experimental design should consider type of event, region and season, among other factors. Collaboration with hydro-modelers and RFC personnel will be necessary in evaluating stream response to QPE input. Stream flow, itself, can be measured via Doppler acoustics on channel cross sections.
- **Develop more automated rain gauge QC techniques:** The first step should be a literature review of existing rain gauge QC algorithms, which would include a review of manual QC techniques presently in use at RFCs and WFOs and an evaluation of which of these may be candidates for automation. One such technique is a quality flag now generated manually, known as "Louzie Data". Also, a survey should be conducted of common sources of rain gauge error, and those sources quantified and addressed. Furthermore, QC techniques using disdrometers to evaluate dual polarization radar-generated precipitation types and amounts should be explored.
- **Determine optimal distribution and type of … precipitation gauges/ disdrometers … to support QPE estimation and verification:** There were assertions that perhaps very dense networks of observing/verification sensors are necessary to significantly reduce sampling errors in verification of radar-based QPE (e.g. 20 stations needed in a 2 x 2 km^2 box to achieve less than 5% sampling error). To assess this, field experiments should be designed to determine optimal distributions of rain gauges, with consideration given to variations in geographic region, season, storm type, basin size, etc. These experiments would incorporate Observing System Simulation Experiment (OSSE) and Observing System Experiment (OSE) methodologies, and outcomes would be assessed from a cost benefit and performance perspective. Disdrometers (optical and video) should similarly be employed to perform precipitation-type and microphysical assessments. There was acknowledgement that acquiring proper permits and permissions from landowners could be a serious challenge. On the other hand, RENCI's sensor inventory and data bus were seen as an opportunity to be leveraged in HMT-SE.
- **Determine the impact of operational radar gaps for QPE:** The first step must be to define the gaps (their location and nature), particularly with regard to situations where important hydrometeorological processes may be missed, e.g. shallow upslope/orographic enhancement; coastal tropical systems; sea breeze or coastal fronts at a distance; overshooting of winter bright band. It was suggested that Q2 could be used as a tool to identify gaps and evaluate their mitigation. Emerging techniques including vertical pointing radars and CASA (cell tower mounted radars) should be employed to address the gaps.
- **Determine the validity of ground-based radar QPE algorithms:** The soon-to-be implemented WSR-88D dual polarization algorithms, including Hydrometeor Classification and Quantitative Precipitation Estimation, were developed for the southern Great Plains; these need to be fine-tuned for the southeast U.S. climate. The fact that the Morehead City, NC radar will be a dual polarization beta site will afford an excellent opportunity to do this. Dense rain gauge networks will be necessary to perform the QPE verification at fine spatial scales; likewise, disdrometer networks will be necessary to verify hydrometeor types and sizes. Vertically pointing radars should also be employed in the design of the field

experiment. Ground-based snowfall measurements will be necessary to quantify radar retrievals of snowfall.

- **Assess usefulness of satellites for QPE:** Several satellite-based sources could be examined and compared vs. "ground truth", including NESDIS Hydro-Estimator, SCaMPR, PERSIANN-CCS, CMORPH, Cloud SAT, TRMM-PR and TRMM-3B42. Satellite and radar-combined solutions have been shown to have promise and could also be investigated. For verification, rain gauge, disdrometer, etc. networks could, again, be used. A particular opportunity may lie in the fact that the next generation NASA Global Precipitation Measurement (GPM) mission will soon be launched, and North Carolina is designated to be a focus area in 2013. This circumstance is seen as potential opportunity for getting budget money for HMT-SE for use in satellite calibration/validation (Cal/Val).

Quantitative Precipitation Forecasting (QPF)

The QPF breakout group reviewed 11 requirements. The group focused primarily on shorter-term forecasts, and did not focus on climate-scale (or even 5-day) forecasts. This focus stemmed from uncertainty about how flood forecast information with longer lead times would be used by the public. In addition to temporal scales, the QPF group discussed spatial scales and determined that there is a need to observe scales ranging from the convective to the synoptic. The question of how far upstream of the focus area the atmosphere needs to be observed, must be addressed. This is important because the data collected in HMT must be archived. These data will help us better understand the microscale (microphysics) and mesoscale processes that impact precipitation, and thus, help improve forecasts.

The QPF group recognized that cold air damming, orographic effects on precipitation, coastal fronts, sea-breezes, and tropical cyclones are among the regional, meteorological phenomena that are critical in modulating QPF; however, prioritization of these sub-topics for inclusion in the HMT study was deferred. In addition, the group recognized that a vital element of HMT is the transition of research to operations. The computing capabilities at individual WFOs and RFCs might pose challenges in terms of processing power, storage, and bandwidth. Since high resolution deterministic and ensemble NWP are key components of quantitative precipitation forecasting, IT/computing support to execute these models and transfer, display, and archive these data will be very important. Assuming these IT/computing issues are addressed, the matter of the training of WFO and RFC forecasters will also be essential for successful R2O. Also, in order for research to be transitioned effectively to operations, HMT results and applications must be effectively integrated into the forecast workflow. HMT will also need to enable and enhance interactions among collaborators such that HMT-developed products and data are available, reliable, usable, and sustainable. In addition, there are tools available to WFOs, RFCs, and NCEP that are not available to the research community. Allowing researchers access to these tools would facilitate the transition of research to operations.

The QPF group also discussed probabilistic QPF. The group consensus was that the *communication* of probabilistic information (forecast uncertainty) is not yet well understood by the general public. Tools will need to be developed for forecasters (both meteorologists and hydrologists), researchers, and the public to effectively use probabilistic QPF. Finally, the group discussed the need for verification and validation tools to help evaluate both NWP and operational QPF, and assess the impact of new techniques and applications. There is an opportunity to leverage the efforts of the Development Testbed Center and activities in other test beds such as the HWT's Spring Program and the OHD Hydrology Laboratory, to support HMT-SE in this area.

Hydro Modeling

The Hydrology Modeling group considered each of the 13 items in the requirements document. The group felt the priorities were appropriate. Ultimately, it was assumed the HMT program leadership will make the final priority decisions.

A number of infrastructure items involving observations and data need to be addressed at the HMT-SE program management level, for the program to be successful. A common database is also needed to store the critical observations that HMT-SE researchers will need. Questions arose with regard to who would create and maintain the database, what the exchange formats would be, etc. Specific issues discussed included bathometric DEMs, rain gauge observations, standard meteorological observations, and soil observations.

There was representation from NWS-OHD in this breakout group, which wasn't available at the first workshop. This facilitated discussion on how ensembles may be created. For example, ensembles can be created by varying the individual model, varying the initial data, or including multiple models. The issues surrounding continuous data assimilation into the model were discussed, as well.

Michael Ek from NCEP discussed how the NOAA LSM (Land Surface Model) is being used to generate streamflow forecasts retrospectively for the past 30 years and how HMT-SE could leverage the results for calibration purposes. Furthermore, an NWS forecaster from Morehead City, Sarah Jamison, provided a number of insights into operational forecasting problems. Her message was that accurate gauge measurements in real time are critical during flooding events. She also related her frustration that key gauges have recently been removed due to budget reasons and how that is impacting flash flood warnings. Rich Patchen (NOS) spoke about OSSE/OSEs and their importance. Finally, the group recognized the opportunity to leverage work already done in the Tar/Neuse on high-resolution, digital elevation models (DEMs) and inundation mapping, by the State of NC and the NWS.

Decision Support Systems (DSS) and Societal Impacts (SI)

About 14 workshop attendees participated in the DSS/SI breakout group to help discuss and formulate a framework for the HMT-SE Science Plan. Participants represented several different NOAA line offices, the North and South Carolina Sea Grant, North Carolina Emergency Management Agency, North Carolina State Climate Office, the academic community, and others.

Starting from the original list of requirements from the Workshop #1, the group identified and prioritized 10 key theme requirements. These requirements fell within 4 broad categories: modeling development, effective data utilization, enhanced communication and dissemination, and training and evaluation.

- Modeling Development: key requirements included the development of hydrometeorological models that would provide increased spatial and temporal resolution for decision support
- Effective Data Utilization: Identified the importance of enhanced NWS "E-19" flood impact information and the ability to more effectively access and disseminate existing data sets (such as inundation maps)
- Enhanced Communication and Dissemination: Focused on the capability of interactive communication for the effective transfer of information relating to decision support
- Training and Evaluation: Supported the development of curricula for decision support.

Research-to-Operations:

The second stated desired workshop outcome (above) was addressed primarily during a *Panel Session on Research to Operations (R2O)* that was held during the afternoon of the second day of the workshop. The panel members and session moderator were listed above. Some of the key themes of the discussion were:

- The role that existing NOAA and NWS institutions play in the process, including NWS' Operations & Service Improvement Process (OSIP) and OHD's variant, the Hydrologic Operations & Service Improvement Process (HOSIP) in defining and refining requirements deemed worthy of moving forward, as well as NOAA's Planning, Programming, Budgeting & Execution System (PPBES) in acquiring the necessary funding. NOAA employees should learn to work through these institutions as well as to improve them
- R2O occurs on different scopes and scales including local, regional and national, and not all require the same level of effort
- A continual feedback and refinement process among researchers, developers, forecasters and end users is necessary for ultimate success
- The role of the Hydrometeorology Testbed in the process should include identifying candidate projects for transition to operations, conducting the research, development, experimentation, demonstration and assessment of those projects, and fleshing out many issues and risks.

More information on R2Ocan be found in the presentations titled *"R2O Overview"* (Waldstreicher) and *"R2O to Accompany Session Remarks"* (Bonnin), which can be found at:
ftp://ftp.etl.noaa.gov/user/hmt/HMT-Southeast/Workshop-2/

Next Steps

The next major step for HMT-SE will be the writing of the Science and Services Plan, which will describe the field projects recommended for inclusion in the testbed and the design for implementation of those projects. The first edition of that report is due out in the fall, 2010*, and a writing team will likely be assembled to assist the HMT Project Manager, Tim Schneider, in achieving this. Also, efforts will continue toward acquiring the funding needed for the HMT-SE field phase, which is anticipated to begin in FY11.

*[*Editorial remark, 14 July 2010: Efforts on the development of a science plan were temporarily deferred for one fiscal year, but are presently being resumed as of the Summer of 2010. As of this writing, there is funding in the President's request for FY2011, which, if approved by Congress, will enable core NOAA HMT capabilities in the West and Southeast – i.e. these are "base funds" to support key infrastructure within NOAA/HMT. While there remains some uncertainty, we are optimistic and are planning for success.*]